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Vullioud et al.

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(54) **TOUCH PROBE**

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(73) Assignee: **TESA SA**, Renens (CH)

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G01B 11/00 (2006.01)

(52) **U.S. Cl.**
CPC ***G01B 11/007*** (2013.01); ***G01B 5/012*** (2013.01)

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USPC 33/559, 558, 561, 503
See application file for complete search history.

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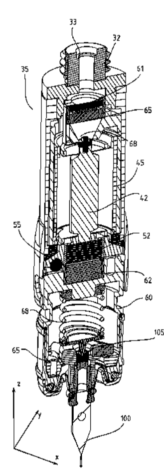
Primary Examiner — Yaritza Guadalupe-McCall
(74) *Attorney, Agent, or Firm* — Maschoff Brennan

(57) **ABSTRACT**

Touch probe comprising a fixed member; a feeler held by one or several elastic elements in a resting position relative to said fixed member, said feeler being capable of moving from said resting position in response to a deflection force; a detection system comprising a light source driven by the displacements of the feeler relative to said fixed member; an optical image sensor receiving the light emitted by said light source; an optical mask interposed on the light path between said light source and said optical image sensor.

32 Claims, 6 Drawing Sheets



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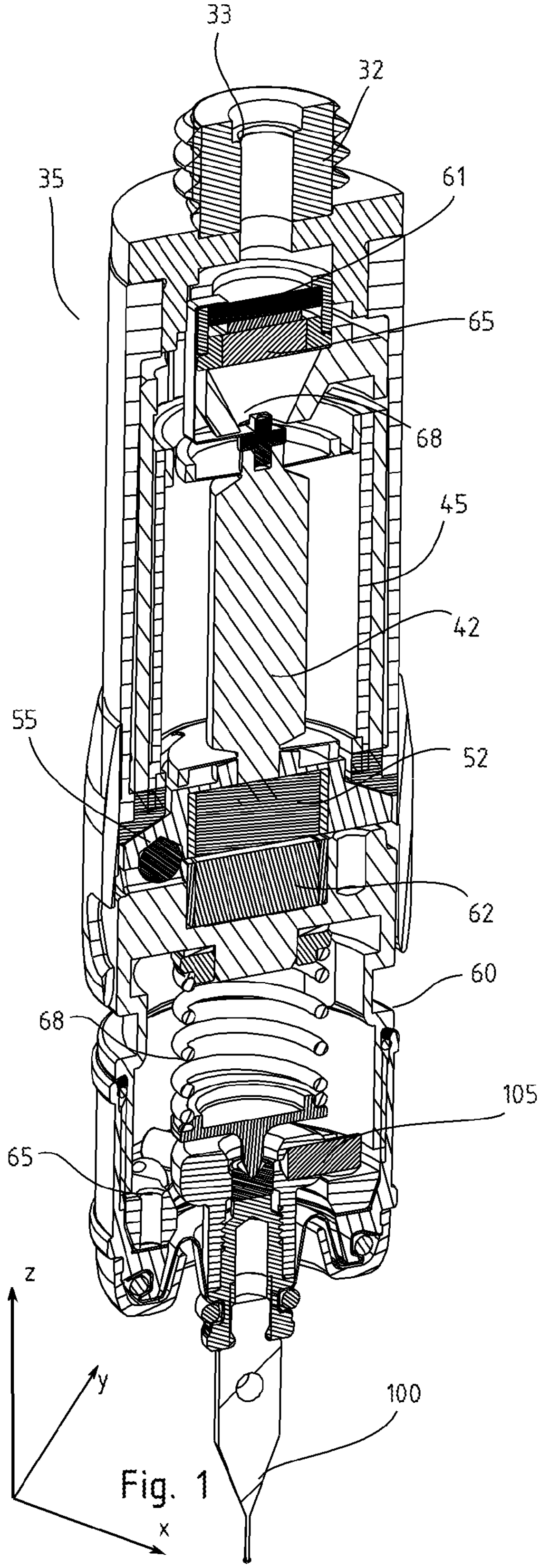


Fig. 1

Fig. 3a

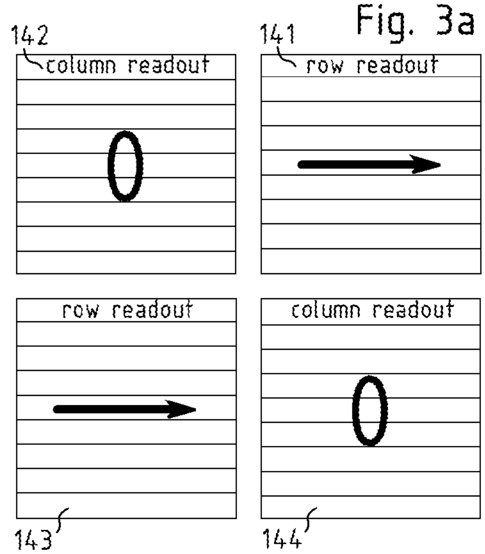


Fig. 3b

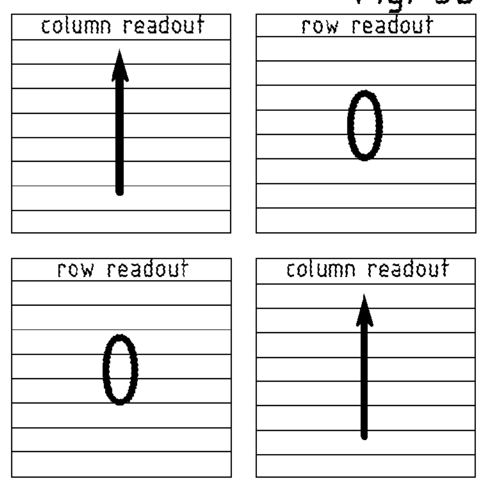
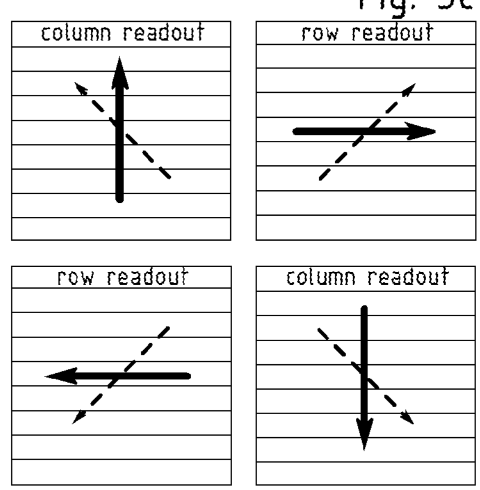


Fig. 3c



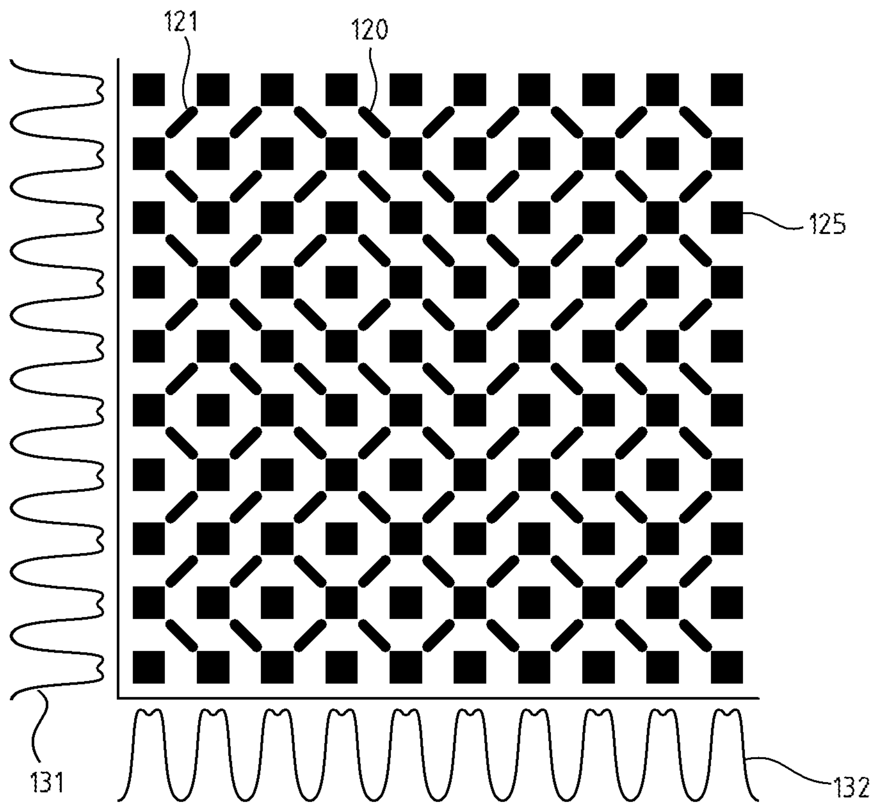

121
120
125
131
132

Fig. 2

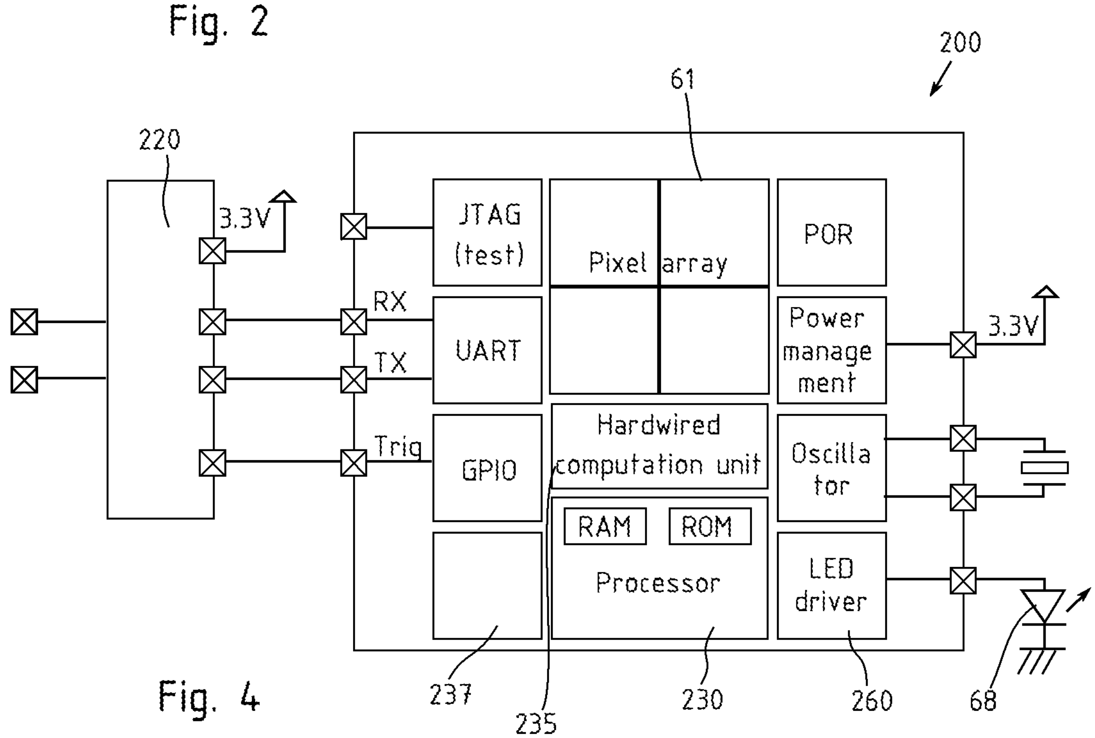

200
61
220
3.3V
JTAG (test)
Pixel array
POR
RX
UART
TX
Power management
3.3V
Trig
GPIO
Hardwired computation unit
Oscillator
RAM
ROM
Processor
LED driver
237
235
230
260
68

Fig. 4

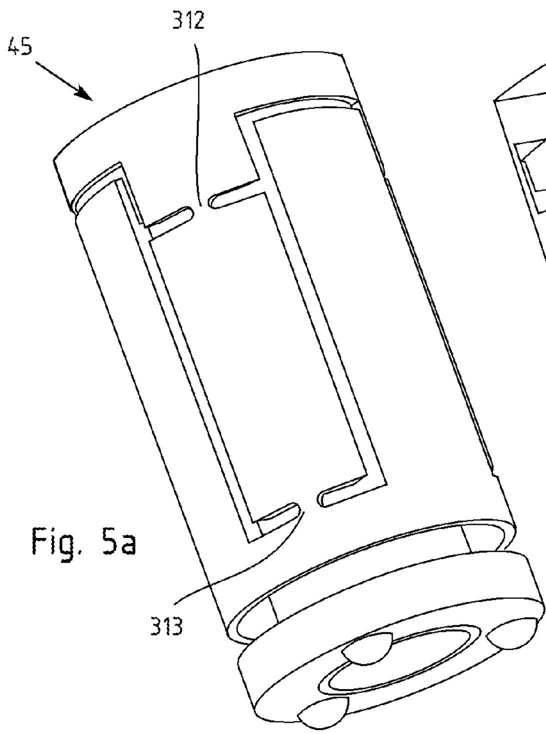


Fig. 5a

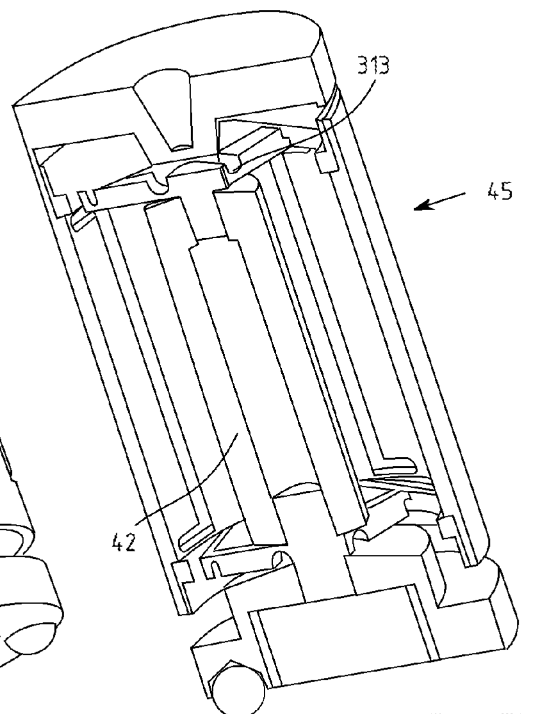


Fig. 5b

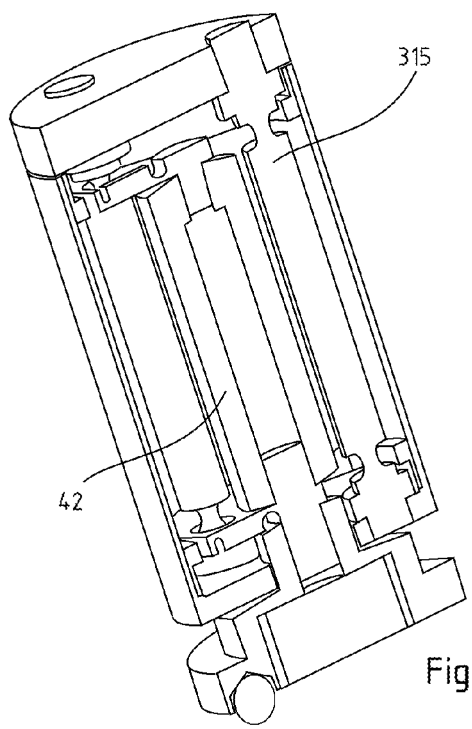


Fig. 6

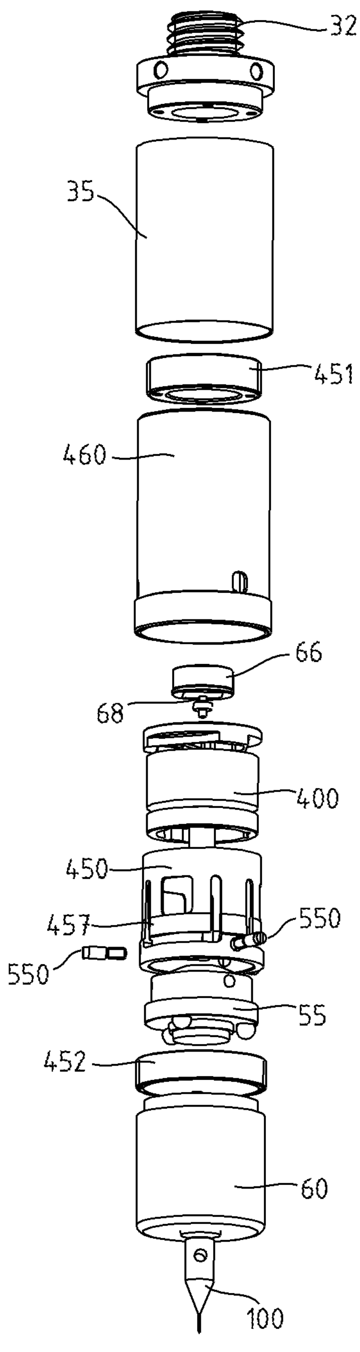

32
35
451
460
66
68
400
450
457
550
550
55
452
60
100

Fig. 7

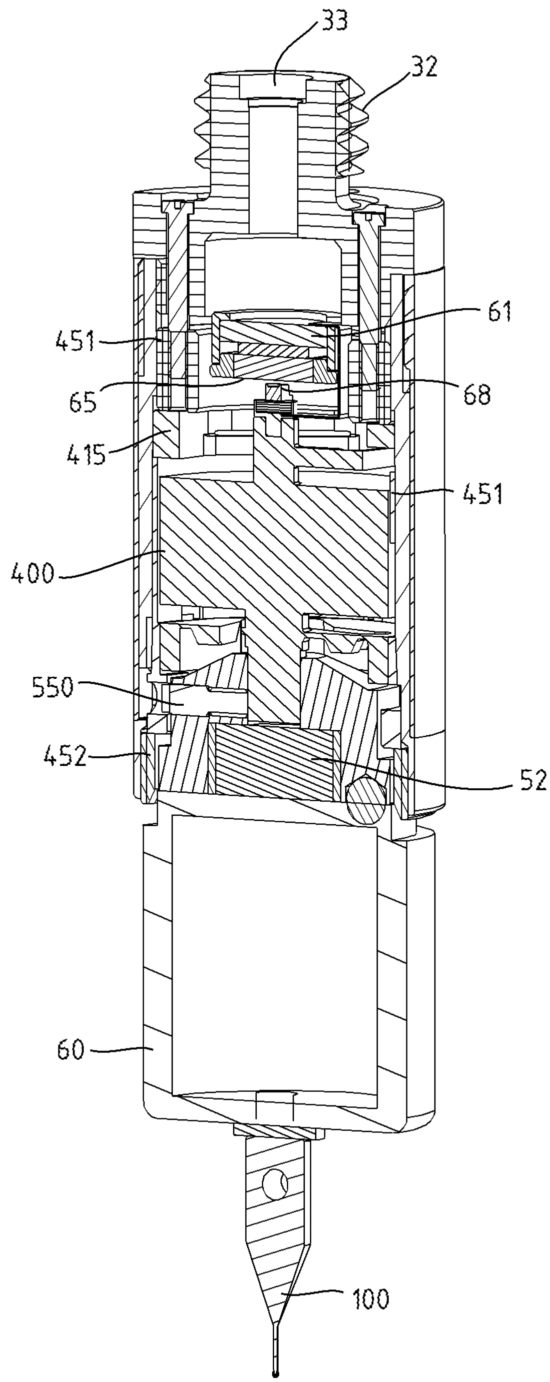
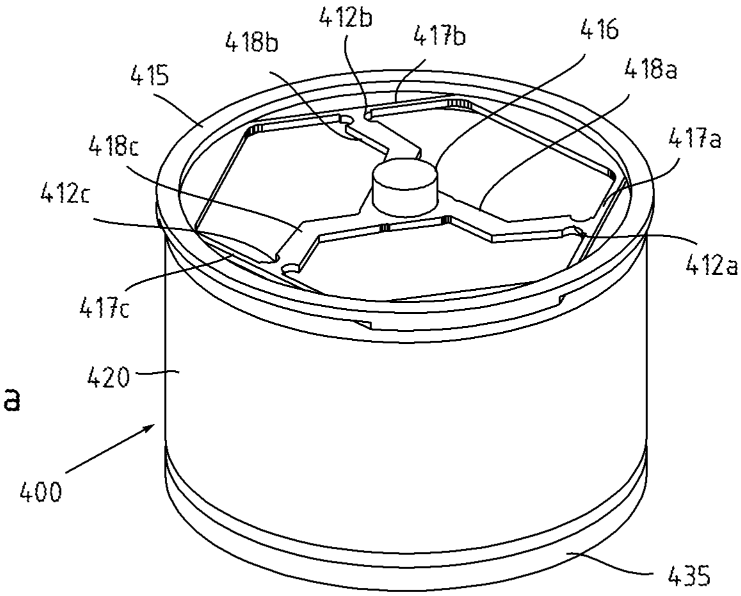
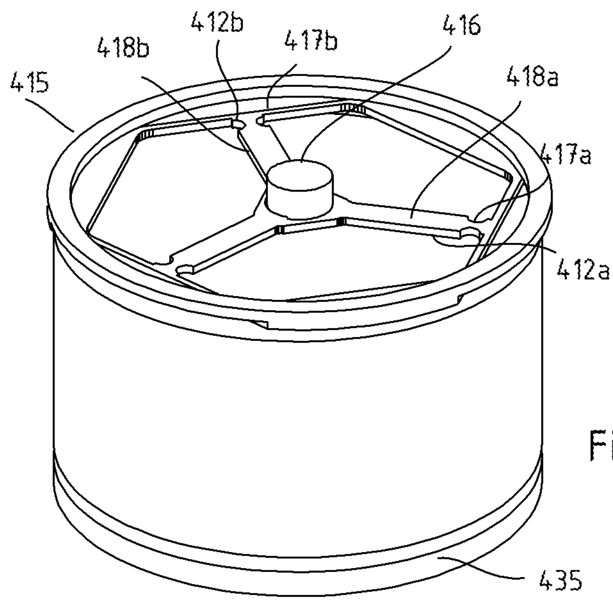

33
32
61
451
65
68
415
451
400
550
452
52
60
100

Fig. 8



412b
418b
417b
416
418a
415
418c
417a
412c
412a
417c
420
400
435

Fig. 9a



412b
418b
417b
416
418a
415
417a
412a
435

Fig. 9b

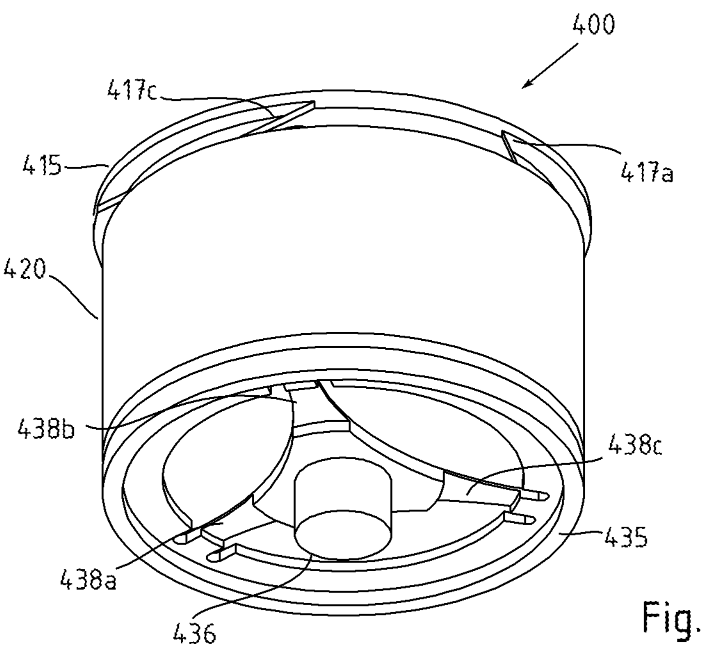

400
417c
415
417a
420
438b
438c
435
438a
436

Fig. 10

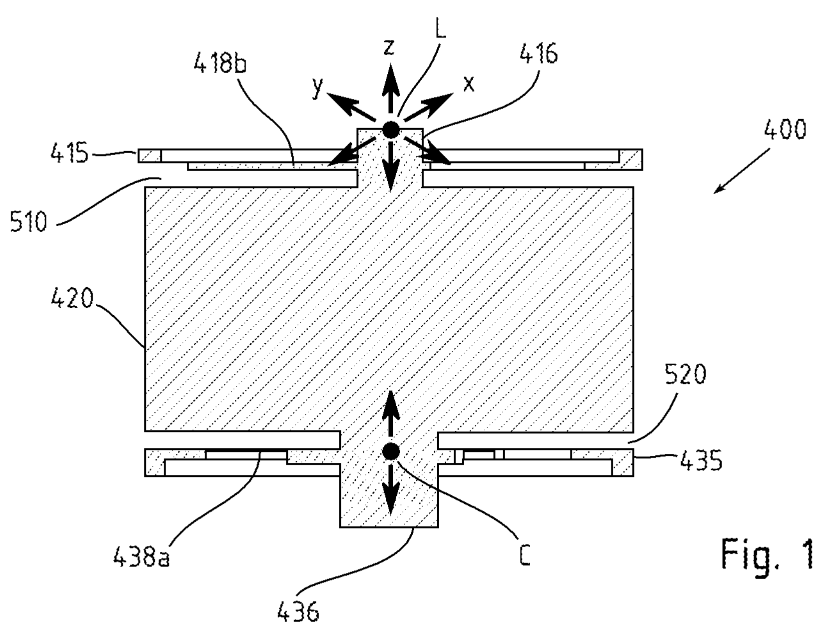

L
z
418b
416
y
x
400
415
510
420
520
435
438a
C
436

Fig. 11

TOUCH PROBE

REFERENCE DATA

The present application claims priority from European patent application EP12156134.4 of Feb. 20, 2012, and from European patent application EP12191264.6 of Nov. 5, 2012, in the name of the present applicant, which are hereby incorporated by reference in their entirety.

FIELD OF THE INVENTION

The present invention concerns touch probes or contact probes for coordinate measuring machines and notably, but not exclusively, trigger-type contact probes.

STATE OF THE ART

Touch probes and their use with measuring machines for measuring coordinates of the surface of a mechanical part are well known in the field of metrology. In a typical case, a contact probe comprises a mechanical interface for assembly onto the mobile platform of a measuring machine, and a stylus, with a ruby sphere at its extremity, designed to contact the surface to be measured. When the stylus touches the part and is moved from its resting position, the probe triggers an electric signal indicating that a contact has occurred. This signal is transmitted to a control unit that records the instantaneous coordinates of the machine and calculates the coordinates of the contact point on the part.

Analog probes, also called scanning probes, are also known which are capable of measuring the deflection of the stylus along one or several axes. These probes are used, as their name indicates, by scanning the surface of the part and measuring the coordinates along a trajectory.

In a known variant, for example as in EP0764827, U.S. Pat. No. 4,270,275 or U.S. Pat. No. 6,760,977, the stylus is fastened onto a support with three radial pins arranged symmetrically, each resting on two spheres integrally united with the probe's body. This arrangement constitutes an isostatic connection with six independent contact points; the relative position of the stylus in relation to the probe's body is thus accurately defined. The trigger signal is generated when one of the pins lifts off the two spheres on which it normally rests, thus interrupting the electric contact between the two spheres. These probes of simple construction combine reliability and accuracy but suffer from several limitations. In particular, the sensitivity of the probe to a transverse force is not constant but varies according to the orientation of the external force, exhibiting three lobes corresponding to the directions of the three pins. This variation of the sensitivity is detrimental to the repeatability of the touch triggering and thus to the quality of the measuring. Altering the arrangement of the pins, as described for example in EP1610087 or DE3713415, can reduce this anisotropy, yet without however eliminating it completely.

European patent application EP0360853 attempts to remedy these problems by proposing a sensor in which the electric circuit is replaced by strain gauges that are directly sensitive to the force applied.

In other embodiments, for example the probes described in documents U.S. Pat. No. 5,435,072 and EP0415579, the contact between the stylus and the part to be measured is detected by a vibration sensor or by an optical sensor.

BRIEF SUMMARY OF THE INVENTION

One aim of the present invention is to propose a touch probe free from the disadvantages of the known touch probes and that notably exhibits a constant sensitivity to lateral forces.

Another aim of the present invention is to propose a more touch probe that is more sensitive and accurate than the prior art probes.

These aims are achieved by a device having the characteristics of the attached claims.

BRIEF DESCRIPTION OF THE FIGURES

Examples of embodiments of the invention are indicated in the description illustrated by the attached figures, in which:

FIG. **1** illustrates a touch probe according to the invention, in cross section.

FIG. **2** illustrates schematically an optical mask that can be used in the frame of the invention.

FIGS. **3**a to **3**c show an image sensor divided into four quadrants.

FIG. **4** shows schematically a processing circuit that can be used in the frame of the invention.

FIGS. **5**a, **5**b, and **6** illustrate elastic structures that can be used in the frame of the invention.

FIGS. **7** and **8** show a variant embodiment of the invention in an exploded view and in cross sectional view.

FIGS. **9**a and **9**b illustrate two possible embodiments of the elastic structure used in the embodiment of FIGS. **7** and **8**.

FIG. **10** shows another view of the elastic structure represented in FIGS. **9**a and **9**b.

FIG. **11** is a cross-section of the elastic element of FIG. **9**b, wherein the degrees of freedom have been represented.

EXAMPLE(S) OF EMBODIMENTS OF THE INVENTION

With reference to FIG. **1**, the inventive touch probe comprises in one embodiment a feeler module **60** with a stylus **100** mounted onto a support **105** held elastically by the spring **66** in a resting position defined by the six contact points between three pints **65** (partly visible) of the support and six balls (not represented) integrally united with the feeler module. This arrangement enables the stylus to move under the action of an external force and to revert exactly to the resting position when this external force ceases to be exerted. As a certain gap (over-travel) is required to stop the movement of the measuring machine when the system detects a contact, this elastic assembly of the stylus makes it possible to limit the contact force during this time frame.

The manner in which the stylus **100** is mounted in the feeler module **60** is not an essential characteristic of the invention and other assembly layouts could be used, depending on need, without leaving the field of the invention.

The feeler module **60** is preferably connected in a removable fashion to the body of the probe **35** in order to be able to easily exchange the styluses depending on the measurement requirements. The feeler module **60** and the probe body can preferably be connected and separated automatically, in a manner compatible with the automatic tool changing systems currently used in measuring machines. In the example illustrated, the connection is achieved by means of the pair of magnets **52** and **62**, placed one in the probe body and the other in the feeler module. In other embodiments, the connection could be achieved by a mechanical connector, for example the automatic connector described in document EP1577050 in the applicant's name. If modularity is not required, the feeler module and the probe body could be connected in a permanent manner.

The body of the probe **35** is provided with a connection device **32** to fasten it to the mobile platform of a measuring machine. In the example illustrated, the connection is achieved by a standard M8 screw **32**, but other connection mechanisms are possible. The axial electric contact **33** enables the electronics inside the probe body to be powered by an external power source, as will be seen further below. If necessary, the single contact **33** could be replaced by a plurality of contacts.

The feeler module is integrally united, through the magnets **52**, **62** or any other suitable connection means, with a support **55** which is held in position inside the body of the probe **35** by en elastic structure **45** so as to be able to follow, within predetermined limits, the deflections of the stylus along the axes x, y, z. The elastic structure, in the frame of the present invention, can have different shapes. The structure **45** will preferably have dimensions such that it exhibits the same elasticity in the three directions.

The rod **42** is integrally united on the lower side with the support **55** and bears on its upper side a light source **68**, for example a light emitting diode (LED). The deflection movements of the stylus are thus converted in proportional displacements of the light source **68**.

According to an important aspect of the invention, the probe body also comprises an image sensor, for example a CCD sensor **61** or any other suitable optical image sensor, juxtaposed to the light source **68** so as to receive the light emitted by the latter. A coded optical mask **65** is interposed on the light path between the source **68** and the image sensor **61**. The optical mask **65** projects onto the sensor a non-uniform distribution of light intensity that moves according to the displacements of the LED source **68**. A processing circuit, preferably integrated on the same silicon chip as the image sensor **61**, determines the deflection of the stylus according to the three dimensions x, y, z relative to the probe body from the distribution of light intensity on the sensor's surface.

Optionally, the inventive touch probe includes a plurality of image sensors juxtaposed to the light source and arranged so as to receive the light emitted by the latter, through a common optical mask or through separate masks for each sensor. As in the variant embodiment described above, the deflection of the stylus in the three dimensions x, y, z is determined from the distribution of the light intensity recorded by the sensors, by means of a processing circuit that can be common to the image sensors or comprising independent processors for the individual sensors.

The operating principles of the transducer constituted by the source **68**, the mask **65** and the image sensor **61** have been described in documents EP1750099B1, EP2169357A1 and WO2010112082A1, and will not be analyzed here in detail. In the example represented in FIG. **2**, the optical mask **65** carries a two-dimensional code comprising a regular array of tiles **125** and a code composed by an array of diagonal segments. In the example shown, for example, the segments parallel to the segment **121** encode a binary value '1' whilst the segments parallel to the segment **120** encode a binary value '0'.

Advantageously, the two-dimensional code represented by the segments enables an absolute positioning with the resolution of the array of tiles **125** whilst the interpolation of the signals **131** and **132** obtained by the projection along the axes of the light distribution makes it possible to determine accurately the relative position in x and y. Other arrangements are however possible.

In order to increase the reading and processing speed, the pixels are optionally grouped into zones, with each zone being dedicated to a specific measurement. In the example illustrated in FIG. **3***a*, the pixels of the image sensor **61** are arranged in four quadrants **141**, **142**, **143**, **144**. The quadrants **141** and **143** arranged diagonally are arranged for determining the displacements in the x direction whilst the two other quadrants are designed for determining the displacements in the y direction. With reference to the example shown in FIG. **2**, the processing circuit could be limited to calculating a single of the two projections **131** respectively **132** in each of the quadrants, along the direction of displacement one wishes to measure, thus limiting the number of operations. The code recorded in the optical mask **65** could also be divided into quadrants and consequently simplified.

Other arrangements are possible within the frame of the invention, comprising variants with a single image sensor not divided into quadrants, or two or more independent image sensors.

According to an alternative embodiment, not illustrated, the optical mask is not present and a non-uniform light source is then used, i.e. a source that generates a non-uniform distribution of light intensity on the surface of the image sensor **61**. For this purpose it would be possible to use an LED with a highly anisotropic emission profile, a laser diode, an optical system generating interference fringes or any other appropriate non-uniform source that enables the processing circuit to determine the deflection of the stylus along the three dimensions x, y, z from the distribution of the light intensity on the sensor's surface.

According to another variant, not illustrated, the optical mask does not comprise a plurality of transparent and opaque regions, as in FIG. **3**, but an appropriate arrangement of transparent regions with different optical characteristics so as to generate a variable distribution of light intensity on the surface of the sensor. An array of lenses can advantageously be used in the optical mask to increase the intensity and the contrast of the light distribution on the sensor.

FIG. **3***a* illustrates the situation in which there is a displacement of the source **68** along the x-axis. The quadrants **141** and **143** record a same displacement whilst the two other quadrants record no variation. Inversely, when the displacement is only in the direction of the y-axis, the two quadrants **142** and **144** record an identical displacement and nothing is measured by the quadrants **141** and **143**, as can be seen in FIG. **3***b*.

FIG. **3***c* illustrates the situation that arises during a displacement along the z-axis. In this case, it is the scale of the image projected by the mask **65** that changes. The quadrants **141** and **143**, and even the quadrants **142** and **144**, measure opposite displacements. In a general case, the relative movement of the source **68** can be decomposed in a superposition of movements in x, y, and z.

In the example described, the image of the mask projected onto said optical image sensor changes depending on the movements of the feeler **100** since the light source **68** is driven by the displacements of the feeler relative to said fixed member. It would also be conceivable, while remaining in the frame of the invention, to drive by the feeler the mask or the image sensor, with the same effect. The invention also includes variant embodiments in which the source, the mask and the sensor remain fixed relative to the probe body but the optical trajectory comprises another mobile optical element capable of modifying the image on the sensor depending on the displacements of the feeler **100**, for example a mirror, a lens, a prism or any other optical element or combination of optical elements driven by the feeler **100**.

The displacements of the light source **68** are proportional to those of the contact stylus **100**. The processing circuit can thus trigger a contact signal when the displacement of the feeler exceeds a determined threshold. Advantageously, this trigger threshold can be modified dynamically according to the measurement conditions, by appropriately reprogramming the processing circuit. It would for example be possible to increase the value of the threshold when the measuring machine moves rapidly in order to avoid false signals determined by the vibrations or corresponding to accelerations and decelerations of the probe, and to reduce the value of the threshold when the machine moves slowly to aim for maximum accuracy. The trigger threshold could also be modulated depending on the stylus used, by selecting a greater threshold when longer and heavier styluses, more sensitive to vibrations, are mounted.

According to one aspect of the invention, the processing circuit can also perform a validation of the trigger signal and distinguish the signals derived from a true contact of the feeler **100** with the part to be measured from false signals due, for example, to vibrations. The discrimination can be achieved based on the duration of the deflection signal or on its time profile, for example.

The probe can also be used in scanning mode, in which the processing circuit indicates the deflection of the stylus along one or several axes, measured by the optical sensor.

According to a variant embodiment, not illustrated, the optical sensor could have a non-plane surface, for example in the shape of a roof or pyramid, to increase the collecting of light and sensitivity to axial displacements.

FIG. **4** illustrates schematically a possible structure of a processing circuit **200** according to one aspect of the invention. The optical sensor **61** is advantageously integrated in the same integrated circuit of the processing circuit. The circuit **200** in this example comprises a microcontroller **230** and a wired logic unit **235** to perform processing operations on the pixels of the sensor **61**, for example projections, averages and/or correlations. The unit **237** is an arithmetic module dedicated to calculating mathematical or trigonometric functions, for example a module using the CORDIC (COordinate Rotation DIgital Computer) techniques. Optionally, the functions of the microcontroller could be fulfilled by other appropriate calculation means, for example a microprocessor or a DSP (digital signal processor).

The circuit **200** preferably also includes environmental sensors, for example an accelerometer and/or a temperature sensor. The accelerometer is used for example to determine the dynamic threshold of the trigger signal or whether the probe has suffered a shock. The signal supplied by the temperature sensor is used in the circuit **200** to compensate temperature errors.

The processing circuit also has an input/output unit **220**, designed for transmitting the position signals to the measuring machine, according to a determined format. When the touch probe is used as a trigger probe, the trigger signal can be transmitted in the form of a variation of the electric current absorbed by the probe. This allows the inventive touch probe to be used as a replacement for classical trigger touch probes. In another variant embodiment of the invention, the input/output unit **220** allows a bi-directional communication with an external unit, for example the controller of the measuring machine or a computer measuring system. The probe can then send through the unit **220** trigger signals and/or deflection measurements and/or validation signals, in an appropriate format. The probe can also receive, through the unit **220**, calibration data or trigger threshold values or any other signal.

FIGS. **5***a*, **5***b* illustrate schematically flexible structures **45** that can be used in the frame of the invention. These structures have several elastic hinges affording them greater flexibility laterally (hinges **312**) or axially (hinges **313**). FIG. **6** illustrates a variant embodiment in which the lateral flexibility is provided by the columns **315**. Other arrangements are however possible.

A preferred embodiment of the inventive touch probe will now be described with reference to FIGS. **7**, **8**, **9***a*, **9***b* and **10**. According to this variant, the probe comprises an elastic structure as previously mentioned, consisting of an integral metallic part **400** connecting the support **55** at its lower extremity and the light source **68** at the opposite extremity.

The elastic structure **400** is more clearly visible in FIGS. **9***a*, **9***b* and **10**, with the FIGS. **9***a* and **9***b* representing two possible variant embodiments of the upper flexible part, as will be seen further below. It has an essentially cylindrical shape and is made of a single integral metallic part without assemblies or welding seams. The elastic structure **400** is preferably achieved by machining, i.e. by turning and milling of a cylinder of appropriate material, for example of tempered steel. It would however also be possible to use in the frame of the invention other manufacturing techniques, for example electro-erosion, laser cutting or any other appropriate method for removing material. It would also be possible to make the elastic structure **400** by molding or by additive manufacturing processes, for example by selective laser sintering, stereolithography, 3D impression etc.

According to one aspect of the invention, the elastic structure **400** comprises an essentially cylindrical central body **420** and two upper and lower end parts, separated from the cylindrical body by two grooves **510** and **520** visible in FIG. **11**. The lower end part comprises a central projection **436** on which the support of the feeler module **55** is fastened, for example through chasing. The upper end part also has a central projection **416** on which the light source **68** is mounted, for example by gluing. The light source is preferably connected to the processing circuit by flexible conductors or a flexible printed circuit.

The two end parts also each comprise a peripheral ring **435** respectively **415** integrally united with the probe body, whilst the lateral surface of the cylindrical body **420** is not in contact with other components and can move under the effect of forces acting on the feeler **100**.

FIGS. **9***a*, **9***b* illustrate two possible variant embodiments of the upper end part of the elastic element **400**. The two variants comprise three tangential girders or blades **417***a*, **417***b*, **417***c* fastened by their extremities to the peripheral ring **415** and three radial arms **418***a*, **418***b*, **418***c* connected on the one hand to the middle point of the corresponding tangential blade and on the other hand to the center of the end part. Notches **412***a*, **412***b*, **412***c* form elastic hinges and improve the flexibility properties of the whole assembly, notably in the axial and lateral directions. The two variant embodiments differ essentially in the shape of the arms **418***a-c* that are straight in the second version and have a more or less accentuated angle in the first in order to increase its flexibility.

The upper end part of the elastic element **400** can advantageously be achieved with conventional machining operations: it is for example possible to mill the arms **418***a-c* through the upper side and detach the tangential blades **417***a-c* from the ring **415** with three milled straight grooves **417***a-c* (better visible in FIG. **10**). The end part is separated from the cylindrical body **420** by the groove **510** (FIG. **11**).

FIG. **10** illustrates a possible structure for the lower end part of the elastic element **400**. The peripheral ring **435** is connected to the central part **436** by three arms **438***a-c* that have a thin central collar in order to increase the flexibility of the whole assembly especially in the axial direction. By comparison with the upper end part, the lower end part is adapted so as to deform under an axial force and is relatively rigid in the directions orthogonal to the axis. Just as the upper part, the lower end part of the elastic element **400** can be made in conventional machining operations.

FIG. **11** shows the flexible element in cross-section and the movements rendered possible by the flexibility of the end parts. As already mentioned, the peripheral rings **435** and **415** are fastened to the probe body, whilst the lower projection **436** is connected to the feeler by the support **55** and the upper projection **416** bears the light source. The forces exerted on the stylus **100** induce different deformations in the end parts according to their respective mechanical characteristics.

The lower end part is designed so as to exhibit a considerable flexibility relative to the axial forces and is by contrast relatively rigid relative to the forces acting transversely to the axis since the collars of the arms **438***a-c* can easily flex but the length of the arms **438***a-c* remains essentially unchanged. Consequently, the point 'C' situated at the intersection of the arms **438***a-c* moves along the axis 'z'.

Simultaneously, the independent flexibility of the arms **438***a-c* allows, if the stylus **100** is subjected to a lateral force, a rotation of the element **420** around the point (C) in the two transverse directions 'x' and 'y'. It is thus possible to model the constraints introduced by the lower end part as a slide enabling the axial displacement of the center 'C' combined with a ball joint of the center 'C'.

Thanks to the arrangement of radial arms connected to tangential blades, the upper end part enables the displacement of the light source at the point **1'** along the three axes 'x', 'y', 'z'. The flexibility of said arms and beams determines the return forces or quantitative flexibility values along the three axes. The elasticity of the structure, defined by the relation k=x/F between the displacement and the force, is of the order of $(1\text{-}10)\times10^{-6}$ m/N. These flexibility values ensure a good sensitivity and quite high self-vibration frequencies beyond the typical vibration frequencies of a coordinate-measuring machine (CMM).

The symmetric arrangement of the arms **418***a-c* and **438***a-c* makes it possible to achieve a highly isotropic flexibility that is essentially independent of the lateral direction of the force. The invention is however not limited to devices with three arms and could have two, four and more arms, depending on circumstances.

The assembly of the elastic structure **400** in the probe will now be described with reference to FIGS. **7** and **8**. According to a preferred embodiment of the invention, the elastic structure **400** is lodged inside a ferrule **450** with flexible branches **757**. When the ferrule **450** is inserted inside the tube **460**, the branches **757** pinch the lower peripheral ring **435** and center it into place. Axially, the lower side of the ferrule **450** rests on the threaded ring **452** and its upper side supports the upper peripheral ring **415** on which a second threaded ring **451** is screwed. Fastening the elastic structure **400** by pinching inside the probe body makes it possible to achieve a rigidity and accurate centering in the axis of the probe, by means of the two upper and lower peripheral rings.

The movements of the stylus and the deformations of the elastic part **400** are limited by the three screws **550** at 120° that engage in appropriate housings in the support of the feeler module **55**. These screws can preferably be adjusted in order to set their position and constitute stops that limit the movements of the feeler module and thus the efforts transmitted to the elastic element **400** as well as its deformation. Other limiting means are however possible.

The stops **550** thus have the function of ensuring the module is aligned and of protecting the elastic part **400**. The inventive probe in fact includes fragile elements, notably the elastic part **400**, that are liable to break or to be altered following excessive efforts, for example in case of shocks. In this case, when the deformation of the elastic element exceeds a predetermined threshold, one of the stops **550** touches the ferrule **450** such that the force is directly transmitted to the latter, thus avoiding any damage and improving the probe's robustness.

The invention claimed is:

1. A touch probe comprising:
- a fixed member;
- a feeler held by one or several elastic elements in a resting position relative to said fixed member, said feeler being capable of moving from said resting position in response to a deflection force;
- a system for detecting displacements of the feeler comprising a light source;
- an optical image sensor receiving the light emitted by said light source; wherein a spatial distribution of intensity on said optical image sensor changes according to the displacements of said feeler,
- wherein said one or several elastic elements consist of a mono-bloc metallic part, and
- wherein the system for detecting displacements is arranged to determine a deflection of the feeler based on a distribution of the light intensity recorded by the optical image sensor.

2. The touch probe of claim **1**, including several optical image sensors receiving the light emitted by said light source.

3. The touch probe of claim **1**, wherein said mono-bloc metallic part has an essentially cylindrical shape with two end elements corresponding to the two bases, said feeler being connected with a center of an end element, and said light source being connected with a center of the opposite end element, where each end element exhibits a peripheral ring integrally united with the probe body and a plurality of deformable elements allowing the displacement of the light source along three axes.

4. The touch probe of claim **3**, wherein said end element whose center is connected with the light source comprises three tangential flexible blades connected by flexible radial arms with the center.

5. The touch probe of claim **3**, wherein said end element whose center is connected with the feeler comprises three flexible collars.

6. The touch probe of claim **1**, comprising an optical mask interposed on the light path between said light source and said optical image sensor.

7. The touch probe of claim **6**, wherein said mask comprises a lens array.

8. The touch probe of claim **1**, wherein said light source is driven by the displacements of the feeler relative to said fixed member.

9. The touch probe of claim **1**, wherein the feeler is connected in a removable fashion to the detection system by means of a magnetic or mechanical connection.

10. The touch probe of claim **1**, wherein the feeler is borne by a changeable module comprising a feeler support held elastically in a resting position by a plurality of positioning elements defining six contact points.

11. The touch probe of claim **1**, further comprising a processing circuit designed to determine the displacements of the feeler in three dimensions from the image recorded by the optical image sensor.

12. The touch probe of claim 11, wherein the processing circuit is designed to trigger a contact signal when the displacement of the feeler exceeds a determined threshold.

13. The touch probe of claim 11, which can be connected to an external power supply, wherein said contact signal is a variation of the electric current absorbed by the probe.

14. The touch probe of claim 11, wherein the processing circuit is designed to trigger a deflection signal depending on the displacements of the feeler.

15. The touch probe of claim 1, wherein the processing circuit includes calculation means, for example a microprocessor, a microcontroller or a DSP or a CORDIC unit.

16. The touch probe of claim 15, wherein said threshold is programmable.

17. The touch probe of claim 1, further comprising a temperature sensor, wherein the processing circuit is designed to compensate the temperature errors on the basis of the signal supplied by the temperature sensor.

18. The touch probe of claim 1, comprising an accelerometer.

19. The touch probe of claim 1, comprising stops arranged to limit the deformation of said elastic elements and ensure robustness during collisions.

20. The touch probe of claim 1, wherein said one or several elastic elements consist of a mono-bloc metallic part produced by an additive manufacturing process.

21. A touch probe comprising:
- a fixed member;
- a feeler held by one or several elastic elements in a resting position relative to said fixed member, said feeler being capable of moving from said resting position in response to a deflection force;
- a system for detecting displacements of the feeler comprising a light source;
- an optical image sensor receiving the light emitted by said light source; and
- a processing circuit designed to determine the displacements of the feeler in three dimensions from the image recorded by the optical image sensor;
- wherein a spatial distribution of intensity on said optical image sensor changes according to the displacements of said feeler,
- wherein the touch probe can be connected to an external power supply,
- wherein said contact signal is a variation of the electric current absorbed by the probe.

22. The touch probe of claim 21, including several optical image sensors receiving the light emitted by said light source.

23. The touch probe of claim 21, wherein said one or several elastic elements consist of a mono-bloc metallic part.

24. The touch probe of claim 21, comprising an optical mask interposed on the light path between said light source and said optical image sensor.

25. The touch probe of claim 24, wherein said mask comprises a lens array.

26. The touch probe of claim 21, wherein the feeler is borne by a changeable module comprising a feeler support held elastically in a resting position by a plurality of positioning elements defining six contact points.

27. The touch probe of claim 21, further comprising a processing circuit designed to determine the displacements of the feeler in three dimensions from the image recorded by the optical image sensor.

28. The touch probe of claim 27, wherein the processing circuit is designed to trigger a deflection signal depending on the displacements of the feeler.

29. The touch probe of claim 21, further comprising a temperature sensor, wherein the processing circuit is designed to compensate the temperature errors on the basis of the signal supplied by the temperature sensor.

30. The touch probe of claim 21, comprising stops arranged to limit the deformation of said elastic elements and ensure robustness during collisions.

31. A touch probe comprising:
- a fixed member;
- a feeler held by one or several elastic elements in a resting position relative to said fixed member, said feeler being capable of moving from said resting position in response to a deflection force;
- a system for detecting displacements of the feeler comprising a light source; and
- an optical image sensor receiving the light emitted by said light source; wherein a spatial distribution of intensity on said optical image sensor changes according to the displacements of said feeler,
- wherein said one or several elastic elements consist of a mono-bloc metallic part that has an essentially cylindrical shape with two end elements corresponding to the two bases,
- wherein said feeler is connected with a center of an end element,
- wherein said light source is connected with a center of the opposite end element, where each end element exhibits a peripheral ring integrally united with the probe body and a plurality of deformable elements allowing the displacement of the light source along three axes, and
- wherein said end element whose center is connected with the light source comprises three tangential flexible blades connected by flexible radial arms with the center.

32. A touch probe comprising:
- a fixed member;
- a feeler held by one or several elastic elements in a resting position relative to said fixed member, said feeler being capable of moving from said resting position in response to a deflection force;
- a system for detecting displacements of the feeler comprising a light source; and
- an optical image sensor receiving the light emitted by said light source; wherein a spatial distribution of intensity on said optical image sensor changes according to the displacements of said feeler,
- wherein said one or several elastic elements consist of a mono-bloc metallic part that has an essentially cylindrical shape with two end elements corresponding to the two bases,
- wherein said feeler is connected with a center of an end element,
- wherein said light source is connected with a center of the opposite end element, where each end element exhibits a peripheral ring integrally united with the probe body and a plurality of deformable elements allowing the displacement of the light source along three axes, and
- wherein said end element whose center is connected with the feeler comprises three flexible collars.

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